Modeling Landslide and Erosion as Sediment Sources to Assess Cost and Benefit of Sedimentation

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Dissertation Summary

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Introduction

Landslide research generally requires the use of soil and geological data, which are not easily available in developing countries due to a lack of financial capital needed to carry out such solutions. Landslides can cause significant damage to residents and can lead to economic losses in these countries. Therefore, analyzing landslide risks based on geographic information system (GIS) and remote sensing techniques is necessary in the case of developing countries. The objectives of research is to develop a methodology, which it can be estimating the spatial distribution of sediment deposition and soil erosion in watershed scale. In this research, the soil erosion in each grid cell was estimated by the Revised Universal Soil Loss Equation (RUSLE) which has been widely used around the world in forests, mountains and agricultural areas to predict average annual soil loss. This method based on a remote sensing data and Geographic Information System (GIS) technique. In addition, analyzing the probability of landslide hazard occurrence in Thailand and relationship between landslide and sediment. Furthermore, analyzing positive effect of sediment on ecology and environment for developing sediment resources management and counter measure plan. Moreover, one of the best goals is to expand people knowledge on positive effect of sediment resources.

Study Area and Data Sources

Thailand is a tropical country, lying off the central of the Southeast Asia peninsular between 97°21' E and 105°37' E longitude and 5°37' N and 20°28' N latitude. Thailand borders between Cambodia and Laos in the east, Laos and Myanmar in the north, Malaysia in the south, Myanmar and Andaman Sea in the west. The total area of the country approximately 513,100 square kilometers. The topography of Thailand can be separated into 5 major physical regions consisting of the central valley, the northern plateau area, the northwest, the northeast, the southeastern coast, and the peninsula. Approximately 20% of Thailand is covered by mountain and hills, especially in the northern and southern regions. In this research, we used 45 hydrological stations operated by the Royal Irrigation Department (RID) to observe sediment discharge. These stations were selected to cover all of Thailand with monthly sediment data from 1998 to 2014 (16 years). Furthermore, we obtained the daily rainfall data from 150 stations during the same period from the Thai Meteorological Department (TMD). The spatial characteristic of this research is described by three base maps consists of topography, soil and land use. The topography data were obtained by elevation model (DEM) obtained from U.S. Geological Survey. There are produced from a continuous data set to allow easy mosaicking. Furthermore, these data are available in ArcGIS software to facilitate their ease of use in variety of image processing and GIS technique.

Methodology

In this research, probability landslide model can be used to assessment landslide hazard map in Thailand. This model was developed by Kawague et al. (2010). They used stepwise logistic regression model to analyze the relationship between probability of landslide and physical parameters such as hydraulic parameters, geographical parameters and geological parameters which are considered to be powerful in the event of landslides. This research endured to estimate landslide damage costs, which landslide damage cost depends on land use data. The landslide damage cost can be classified to 4 categories consists of cost in urban area, agriculture area, aquaculture area, and forest area respectively. The land price data between 2016 and 2019 was collected from the treasury department of Thailand for estimating urban area damage cost. The agriculture and aquaculture data in 2016 is collected by the ministry of agriculture and cooperatives of Thailand. Furthermore, soil erosion model can be used to analyze soil erosion from the catchment. Erosion model is necessary to develop land use planning. In this study, soil erosion was analyzed by remote sensing data and GIS software. The soil erosion in each grid cell was estimated by the Revised Universal Soil Loss Equation (RUSLE) (Reanard et al., 1997). This method has been broadly used around the world in mountain, forest, including agriculture area to assess average annual soil loss. Moreover, new technique was developed to estimate the capacity of sediment yield or deposition in each sub catchment by modifying the original RUSLE method. It was assumed that the amount of sediment flow from one grid cell to another downstream grid cell depends on the sediment yield of the original grid cell compared to the average sediment yield capacity of the whole catchment. All catchments were considered, and average spatial parameters were calculated for each catchment.

Results

Landslide hazard map

The landslide probability model was used to assess landslide hazard mapping and combined with the extreme rainfall results and slope data. For hazard map, this study summarized the landslide probabilities for each scenario in terms of the return period consists of 5, 10, 30, 50 and 100 year respectively. The results showed that the northern and southern regions of Thailand have a landslide hazard risk. Landslides in the southern region would occur as a result of heavy rainfall with a 10-year return period, while landslides in the northern region would be the result of rainfall with a 30-year return period. Most areas in the northern region with a high landslide risk were assigned the same high probability. The result of landslide prediction shows that the probability of this event occurring over a 5-year return period is approximately 23 %, and the probability occurring over a 50-year return period increases to 96 %. Furthermore, high-risk areas were identified in Krabi province, where landslide event occurrence exceeds 50 % over a 50-year return period. In addition, the landslide hazard map was validated by a historical map of landslide events in Thailand. The results from landslide probability map correspond to the landslide events. These results confirm that the probability of the landslide model can predict long-term landslide event occurrence in Thailand.

This study analyzed the probability of landslide occurrences in Thailand with changes in climatic conditions using the landslide probability model with daily extreme rainfall. Furthermore, this chapter estimated the impact of climatic conditions on the probability of landslide occurrences in the future under the RCP 4.5 and RCP 8.5 scenarios. The probability of landslide occurrence is dependent on topographic and geological effects, hydraulic gradients and relief energy levels. The results indicate that the probabilities of the landside model can estimate landslide disaster hazards corresponding to the history of landslide disasters in Thailand. In addition, the climate model's scenarios estimate that the probability of landslide occurrence will increase in the future. Future climatic patterns under the RCP 8.5 scenario over a return period of 100 years show that areas presenting landslide hazard probability levels of more than 90 % will expand to 80 % of the entire area. Therefore, the results of this section present new challenges regarding the protection and mitigation of landslides under climate variability in Thailand. Moreover, probability analyses of landslides based on daily extreme rainfall levels will be of use for developing countermeasures regarding landslide disasters in regions for which observed rainfall data are unavailable.

Soil Erosion and Deposition

This study determination using RUSLE model for Thailand has revealed the severity of soil erosion. The parameters of the RUSLE including rainfall, soil, and land use were calculated in each grid cell from a digital elevation model with of 1 square kilometer resolution. The soil erosion was calculated according to Eq. 4.28 after all parameters of RUSLE method were assigned to each grid cell. The results shown that the average annual soil erosion in Thailand is approximately 650 m^3/km^2/year. The results shown that different magnitudes of soil erosion occur in every part of Thailand, but significantly higher magnitudes occur in the northern and southern parts of the country. The northern part of Thailand is an upstream area of many rivers such as Chao Phraya, Ping, Wang, Yom, and Nan Rivers, which these rivers are important to agriculture activities of this country. There is significant evidence that the upstream area of basin in Thailand has the potential to release sediment during erosion to downstream. Furthermore, this result can be attributed to the effects of the topography, geology and land cover, which have the potential to enhance erodibility.

Nowadays the GIS techniques are simple and cheap cost tools for modeling soil loss, with the purpose of assessing erosion potential. Many research have explained sediment sources and soil erosion using GIS techniques for analyzing soil erosion problem. Nevertheless, a proper understanding of soil deposition, as well as soil erosion, is of prime importance for planning counter measures. Models that were employed in previous studies were capable of simulating only sediment erosion and were unable to predict the spatial distribution of soil deposition.

Therefore, this research efforts to analyze sediment deposition by modifying the original RUSLE method for estimating sediment capacity in sub catchment scale. The sediment yield capacity of the whole catchment was estimated by the spatially averaged parameters assigned in the RUSLE method. The results shows that the northwest part of the country has a higher sediment yield capacity than the other areas. The averaged catchment sediment yield capacity was then compared with the sediment yield estimated in each grid cell. If the calculated sediment yield potential in a grid cell was smaller than the average value, that grid cell was considered to be a deposition cell. The magnitude of the difference of the negative values indicates the capacity of sediment deposition in each grid cell. In contrast, when the calculated sediment yield potential in a grid cell was higher than the averaged catchment value, sediment erosion occurs. The grid cells with positive values depict the areas estimated to be susceptible to sediment erosion. The spatially averaged potential of annual sediment deposition in Thailand is 257 $m^3 km^{-2}$ $year^{-1}$.

Benefit of sediment

This research analyzed the benefits and costs of sediment in Thailand using remote sensing and GIS techniques and applied original RUSLE model to estimate the potential of sediment deposition. New technique can be applied to estimate the benefits of sediment to the private and public sectors in large areas. The results indicated that the sediment may benefit the private sector with a value of approximately 2,040 USD per square kilometer, and the average benefit at the sub-district scale is approximately 575,000 USD per year. Nevertheless, the average benefit to public sector in each sub-district of Thailand cost 16,257 USD per year, and this benefit greater than 15,000 USD per year mostly in mountainous areas. In conclusion, this analysis may enable assessments of the economic benefits of sediment resources, while the applicability of this method still needs further development to adapt to various topographical and climatic conditions.